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PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF RECEIPT OF RECORD COPY

(PCT Rule 24.2(a))

受付
12.3.13
[illegible]

To:

AOYAMA, Tamotsu
Aoyama & Partners
Imp Building, 3-7, Shiromi 1-chome, Chuo-ku
Osaka-shi, Osaka 540-0001
JAPON

Date of mailing (day/month/year)	IMPORTANT NOTIFICATION
02 February 2000 (02.02.00)	
Applicant's or agent's file reference	**International application No.**
661451	PCT/JP00/00193

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. (for all designated States except US)
KASAHARA, Mitsuhiro et al (for US)

International filing date	:	18 January 2000 (18.01.00)
Priority date(s) claimed	:	22 January 1999 (22.01.99)
Date of receipt of the record copy by the International Bureau	:	28 January 2000 (28.01.00)
List of designated Offices	:	

EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
National :CN,KR,US

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- [X] time limits for entry into the national phase
- [X] confirmation of precautionary designations
- [X] requirements regarding priority documents

A copy of this Notification is being sent to the receiving Office and to the International Searching Authority.

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer: Masashi HONDA
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

Form PCT/IB/301 (July 1998)

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外国方式

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PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

受付 12.3.31 特許庁

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

AOYAMA, Tamotsu
Aoyama & Partners
Imp Building, 3-7, Shiromi 1-chome, Chuo-ku
Osaka-shi, Osaka 540-0001
JAPON

Date of mailing (day/month/year) 22 March 2000 (22.03.00)	
Applicant's or agent's file reference 661451	IMPORTANT NOTIFICATION
International application No. PCT/JP00/00193	International filing date (day/month/year) 18 January 2000 (18.01.00)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 22 January 1999 (22.01.99)
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An asterisk(*) appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The letters "NR" appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
22 Janu 1999 (22.01.99)	11/14446	JP	03 Marc 2000 (03.03.00)

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

Juan Cruz

Telephone No. (41-22) 338.83.38

003180851

PATENT COOPERATION TREATY

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From the INTERNATIONAL BUREAU

To:
AOYAMA, Tamotsu
Aoyama & Partners
Imp Building, 3-7, Shiromi 1-chome, Chuo-ku
Osaka-shi, Osaka 540-0001
JAPON

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

Date of mailing (day/month/year)	
27 July 2000 (27.07.00)	
Applicant's or agent's file reference	**IMPORTANT NOTICE**
661451	

International application No.	International filing date (day/month/year)	Priority date (day/month/year)
PCT/JP00/00193	18 January 2000 (18.01.00)	22 January 1999 (22.01.99)

Applicant
MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   KR,US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   CN,EP

   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   27 July 2000 (27.07.00) under No. WO 00/43979

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a demand for international preliminary examination must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the national phase, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer
J. Zahra

Telephone No. (41-22) 338.83.38

Continuation of Form PCT/IB/308

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

Date of mailing (day/month/year)	IMPORTANT NOTICE
27 July 2000 (27.07.00)	
Applicant's or agent's file reference	**International application No.**
661451	PCT/JP00/00193

The applicant is hereby notified that, at the time of establishment of this Notice, the time limit under Rule 46.1 for making amendments under Article 19 has not yet expired and the International Bureau had received neither such amendments nor a declaration that the applicant does not wish to make amendments.

TENT COOPERATION TREAT

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
661451		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/JP 00/00193	18/01/2000	22/01/1999
Applicant		
MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

[ ] the text is approved as submitted by the applicant.

[X] the text has been established by this Authority to read as follows:

APPARATUS AND METHOD FOR MAKING A GRAY SCALE DISPLAY WITH SUBFRAMES

5. With regard to the **abstract,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

[X] as suggested by the applicant.

[ ] None of the figures.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

[redacted] national Application No
[redacted]/JP 00/00193

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G09G3/28 G09G3/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 740 253 A (FUJITSU LTD.) 25 April 1997 (1997-04-25)	1,17
A	abstract page 28, line 1 -page 31, line 5 page 54, line 15 - line 28; figures 17-20,57-71	2-16, 18-32

X,P	EP 0 893 916 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 27 January 1999 (1999-01-27)	1,17
A	abstract column 4, line 49 -column 5, line 17 column 7, line 52 -column 8, line 13 column 12, line 43 - line 50 column 14, line 3 - line 20; figures 1,2,11	2-16, 18-32

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 June 2000	15/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	O'Reilly, D

1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

[redacted]ation on patent family members

[redacted]rnational Application No
[redacted]CT/JP 00/00193

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2740253 A	25-04-1997	JP 10031455 A	03-02-1998
EP 893916 A	27-01-1999	JP 11231827 A	27-08-1999
		JP 11212517 A	06-08-1999

PCT REQUEST

661451

Original (for SUBMISSION) - printed on 17.01.2000 03:51:09 PM

0 0-1	**For receiving Office use only** International Application No.	
0-2	International Filing Date	
0-3	Name of receiving Office and "PCT International Application"	

0-4 0-4-1	**Form - PCT/RO/101 PCT Request** Prepared using	PCT-EASY Version 2.90 (updated 15.12.1999)
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	Japanese Patent Office (RO/JP)
0-7	**Applicant's or agent's file reference**	661451
I	**Title of invention**	APPARATUS AND METHOD FOR PERFORMING A GRAY SCALE DISPLAY USING A SUBFIELD METHOD
II II-1 II-2 II-4 II-5 II-6 II-7	**Applicant** This person is: Applicant for Name Address: State of nationality State of residence	 applicant only all designated States except US MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. 1006, Oaza Kadoma Kadoma-shi, Osaka 571-8501 Japan JP JP
III-1 III-1-1 III-1-2 III-1-4 III-1-5 III-1-6 III-1-7	**Applicant and/or inventor** This person is: Applicant for Name (LAST, First) Address: State of nationality State of residence	 applicant and inventor US only KASAHARA, Mitsuhiro 3-17-3, Nagaonishimachi Hirakata-shi, Osaka 573-0162 Japan JP JP

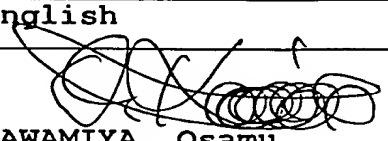
PCT REQUEST 661451

Original (for SUBMISSION) - printed on 17.01.2000 03:51:09 PM

III-2	**Applicant and/or inventor**	
III-2-1	This person is:	applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	ISHIKAWA, Yuichi
III-2-5	Address:	2-32-1-301, Tamakushi Ibaraki-shi, Osaka 567-0895 Japan
III-2-6	State of nationality	JP
III-2-7	State of residence	JP
III-3	**Applicant and/or inventor**	
III-3-1	This person is:	applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	MORITA, Tomoko
III-3-5	Address:	1-8-10-603, Deguchi Hirakata-shi, Osaka 573-0065 Japan
III-3-6	State of nationality	JP
III-3-7	State of residence	JP
IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name (LAST, First)	AOYAMA, Tamotsu
IV-1-2	Address:	AOYAMA & PARTNERS IMP Building, 3-7, Shiromi 1-chome, Chuo-ku Osaka-shi, Osaka 540-0001 Japan
IV-1-3	Telephone No.	06-6949-1261
IV-1-4	Facsimile No.	06-6949-0361
IV-2	**Additional agent(s)**	additional agent(s) with same address as first named agent
IV-2-1	Name(s)	KAWAMIYA, Osamu
V	**Designation of States**	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE and any other State which is a Contracting State of the European Patent Convention and of the PCT
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	CN KR US

PCT REQUEST 661451

Original (for **SUBMISSION**) - printed on 17.01.2000 03:51:09 PM

V-5	**Precautionary Designation Statement** In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.		
V-6	**Exclusion(s) from precautionary designations**	NONE	
VI-1	**Priority claim of earlier national application**		
VI-1-1	Filing date	22 January 1999 (22.01.1999)	
VI-1-2	Number	Patent Application No. 11-14446	
VI-1-3	Country	JP	
VI-2	**Priority document request** The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	VI-1	
VII-1	**International Searching Authority Chosen**	European Patent Office (EPO) (ISA/EP)	
VIII	**Check list**	number of sheets	electronic file(s) attached
VIII-1	Request	4	–
VIII-2	Description	35	–
VIII-3	Claims	7	–
VIII-4	Abstract	1	661451.txt
VIII-5	Drawings	8	–
VIII-7	TOTAL	55	
	Accompanying items	paper document(s) attached	electronic file(s) attached
VIII-8	Fee calculation sheet	✓	–
VIII-9	Separate signed power of attorney	✓	–
VIII-10	Copy of general power of attorney	✓	–
VIII-16	PCT-EASY diskette	–	diskette
VIII-17	Other (specified):	revenue stamps of transmittal fee for receiving office	–
VIII-18	**Figure of the drawings which should accompany the abstract**	1	
VIII-19	**Language of filing of the international application**	English	
IX-1	**Signature of applicant or agent**		
IX-1-1	Name (LAST, First)	KAWAMIYA, Osamu	

PCT REQUEST

661451

Original (for **SUBMISSION**) - printed on 17.01.2000 03:51:09 PM

FOR RECEIVING OFFICE USE ONLY

10-1	**Date of actual receipt of the purported international application**	
10-2	**Drawings:**	
10-2-1	Received	
10-2-2	Not received	
10-3	**Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application**	
10-4	**Date of timely receipt of the required corrections under PCT Article 11(2)**	
10-5	**International Searching Authority**	ISA/EP
10-6	**Transmittal of search copy delayed until search fee is paid**	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	**Date of receipt of the record copy by the International Bureau**	

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G09G 3/28, 3/34 — A1

(11) International Publication Number: **WO 00/43979**

(43) International Publication Date: 27 July 2000 (27.07.00)

(21) International Application Number: PCT/JP00/00193

(22) International Filing Date: 18 January 2000 (18.01.00)

(30) Priority Data:
11/14446 22 January 1999 (22.01.99) JP

(71) Applicant *(for all designated States except US)*: MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. [JP/JP]; 1006, Oaza Kadoma, Kadoma-shi, Osaka 571-8501 (JP).

(72) Inventors; and

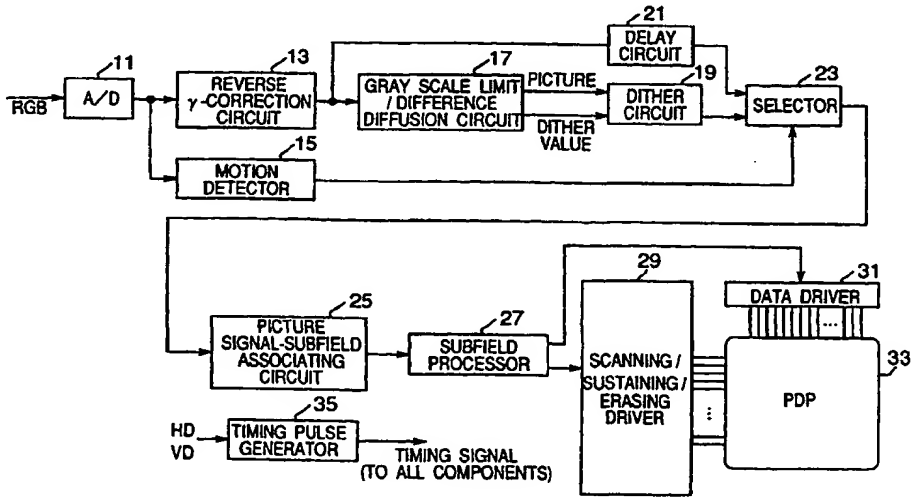
(75) Inventors/Applicants *(for US only)*: KASAHARA, Mitsuhiro [JP/JP]; 3-17-3, Nagaonishimachi, Hirakata-shi, Osaka 573-0162 (JP). ISHIKAWA, Yuichi [JP/JP]; 2-32-1-301, Tamakushi, Ibaraki-shi, Osaka 567-0895 (JP). MORITA, Tomoko [JP/JP]; 1-8-10-603, Deguchi, Hirakata-shi, Osaka 573-0065 (JP).

(74) Agents: AOYAMA, Tamotsu et al.; Aoyama & Partners, Imp Building, 3-7, Shiromi 1-chome, Chuo-ku, Osaka-shi, Osaka 540-0001 (JP).

(81) Designated States: CN, KR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: APPARATUS AND METHOD FOR MAKING A GRAY SCALE DISPLAY WITH SUBFRAMES



(57) Abstract

The invention provides an apparatus and a method applied to a plasma display panel or other display panel, achieving a gray scale display by using a plurality of weighted subfields. The apparatus comprises a gray scale limiting/difference diffusion circuit (17) for converting gray scale levels in a supplied image signal to specific gray scale levels that do not easily create pseudo contours in moving picture areas and to intermediate gray scale levels between the specific gray scale levels, and diffusing the difference between the converted gray scale level and the original gray scale level to adjacent pixels, and a dither circuit (19) for generating a video signal to display the converted gray scale level from the circuit (17) alternately in even and odd fields. The dither circuit (19) generates the video signal in which the gray scale levels offset the dither level above and below the dithered gray scale are alternately presented when the converted gray scale level is a dithered gray scale.

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Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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EE	Estonia	**LR**	Liberia	**SG**	Singapore		

DESCRIPTION

APPARATUS AND METHOD FOR MAKING A GRAY SCALE DISPLAY WITH SUBFRAMES

Technical Field

The present invention relates to a display apparatus such as a plasma display panel (PDP) or digital mirror device (DMD), and to a related display method, whereby a gray scale display is achieved by dividing a single image field into a plurality of subfields.

Background Art

The pixels in plasma display panels and some other types of image display panels can only be driven at two levels, on or off. A so-called subfield method is therefore typically used in such display panels to achieve a display of motion picture with gray scale. This subfield method achieves a gray scale display by dividing each image field into a plurality of two-value subfields weighted for presentation on screen for different time periods. The weight of each subfield corresponds to the light emitted when that subfield is presented. More specifically, each subfield is assigned a luminance weight indicative of the number of times and the period for which pixels are switched on to display the subfield. A desired display luminance is achieved by selecting the combination of subfields which will achieve the desired gray scale.

Fig. 6 shows the time relationship the subfields of a single field in a typical subfield method. In this example, each field is divided into eight subfields, that is, subfields 1 to 8, which are assigned a luminance weight of 1,

2, 4, 8, 16, 32, 64, and 128, respectively. Each subfield is further divided into a set-up period T1, write period T2, and sustain period T3. The set-up period T1 discharges any residual charge in the subfield. Data for turning each pixel of the PDP either on or off is then written in the write period T2. Those pixels that are to be turned on based on the data written in the write period T2 are then turned on all at once during the sustain period T3, and the subfields are turned on in sequence from subfield 1 to subfield 8.

A 256-level display with gray scales from 0 to 255 can be achieved using subfields as shown in Fig. 6 by driving the subfields in various combinations. For example, a gray scale level of 7 can be achieved by turning pixels on for subfields 1 to 3, and a gray scale level of 21 can be achieved by using subfields 1, 3, and 5.

It is therefore possible with this subfield method to time-divide each image field into a plurality of subfields, select from among this plurality of time-divided subfields the subfields needed to achieve a desired gray scale level, and drive the display pixels for the time determined by the selected subfields to present the desired gray scale level.

In display devices using this subfield method are known, however, to suffer from pseudo contours appearing in the motion pictures. These pseudo contours will be further described below.

Let us assume that an image field has been time divided into subfields with weights of 1, 2, 4, 8, 16, 32, 64, and 128, and that image pattern X shown in Fig. 7 moves by two pixels horizontally on PDP screen 33. In addition, image pattern X comprises pixels P1 and P2 with gray scale level of 127, and adjacent pixels P3 and P4 with level of 128. The subfields that are

driven to achieve these gray scale levels in image pattern X are shown in Fig. 8. Note that the horizontal direction in Fig. 8 corresponds to the horizontal direction of the PDP screen 33, and time is shown on the vertical direction. The emitting subfields are shaded.

When image pattern X is still, the gray scale level observed by a viewer is determined by the combination of emitting subfields through line A-A', and the image gray scale level is normally perceived as intended. However, when the image pattern X moves horizontally across the screen as indicated in Fig. 7, the viewer's sight line would effectively moves in B-B' or C-C' direction in Fig. 8. When the sight line moves in B-B' direction, the observer sees subfields 1 to 5 of pixel P4, subfields 6 and 7 of pixel P3, subfield 8 of pixel P2. Because these subfields are integrated in time field, the viewer would observe gray scale level 0. Conversely, when the sight line is through C-C', the viewer observes subfields 1 to 5 of pixel P1, subfields 6 and 7 of pixel P2, and subfield 8 of pixel P3. In this case, the viewer would observe gray scale level of 255. More particularly, the perceived gray scale level is significantly different from the intended gray scale level of 127 or 128, and is seen by the human eye as a pseudo contour.

This problem of pseudo contours is particularly pronounced when this method of using weighted subfields is used and the luminance levels of adjacent pixels are 63 and 64, 191 and 192, and similar combinations which require a significant change in the pattern of emitting subfields to achieve a minimal change in gray scale. Contour lines such as these appearing only in moving picture images are known as pseudo contour noise and are a factor in image quality deterioration (see pseudo contour noise appearing in displays of

PWM controlled moving pictures, Technical Report of the Inst. of Television Engineers of Japan, Vol. 19, No. 2, IDY95-21, pp. 61 - 66.).

Disclosure of Invention

The present invention is therefore directed to a display apparatus and display method for reducing pseudo contours in moving picture regions of a video image presented on a plasma display panel or similar two-value display panel in which gray scale expression is achieved by dividing one image field into a plurality of subfields. A display apparatus according to the invention performs gray scale display by dividing one field of picture into a plurality of weighted subfields and by controlling each subfield to emit or not emit based on the gray scale level of pixel in the picture.

The apparatus comprises a conversion unit and a first diffusion unit. The conversion unit selectively converts a gray scale level of the pixel to one gray scale level in a first gray scale group ("display-use gray scale group") or one gray scale level in a second gray scale group ("dithered gray scale group"). The first gray scale group includes a plurality of gray scale levels which is used for actual display. The gray scale level in the first gray scale group is expressed by the combination of the subfields. The second gray scale group includes a plurality of gray scale levels each of which has a value in the middle of the gray scale levels in the first gray scale group. The first diffusion unit generates a video signal. The video signal displays a gray scale level obtained by the conversion unit when the gray scale level obtained by the conversion unit is in the first gray scale group, while the video signal displays a gray scale level in the first gray scale group which is obtained by diffusing a

predetermined value corresponding to the gray scale level in the second gray scale group when the gray scale level obtained by the conversion unit is in the second gray scale group.

The first gray scale group may include gray scale levels each of which is achieved by subfields in which there is no non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level. The first gray scale group may include gray scale levels each of which is achieved by subfields in which there is at most one of non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level. The first gray scale group may include gray scale levels each of which is achieved by subfields in which there is at most two of non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level.

The non-emitting subfield may exclude a subfield having the minimum weight. The non-emitting subfield may exclude a subfield having the minimum weight and a subfield having the next succeeding minimum weight. The non-emitting subfield may exclude a subfield having the minimum weight, a subfield having the next succeeding minimum weight and a subfield having the third succeeding minimum weight.

The first diffusion unit may generate the video signal to display the gray scale level in the first gray scale group which is obtained by adding or subtracting the value corresponding to the gray scale to be displayed to or from the gray scale level in the second gray scale group when the converted gray

scale level from the gray scale conversion unit is in the second gray scale group.

The apparatus may further comprise a second diffusion unit for diffusing a difference between the gray scale level of pixel to be displayed and the converted gray scale level to pixels adjacent to the pixel to be displayed with predetermined ratio.

The second diffusion unit may determine a value to be diffused in horizontal direction based on a lower bits of all bits which indicate the gray scale level of pixel to be displayed, and a value to be diffused in vertical direction based on a value obtained by removing the lower bits from a difference between the gray scale level of the pixel to be displayed and the converted gray scale level.

A display method according to the invention performs gray scale display by dividing one field of picture into a plurality of weighted subfields and by controlling each subfield to emit or not emit based on the gray scale level of pixel in the picture. The method comprises selectively converting a gray scale level of the pixel to one gray scale level in a first gray scale group which includes a plurality of gray scale levels to be used for actual display, or to one gray scale level in a second gray scale group which includes a plurality of gray scale levels each of which has a value in the middle of the gray scale levels in the first gray scale group, and generating video signal. The gray scale level in the first gray scale group is expressed by the combination of the subfields. The video signal displays a gray scale level obtained by the conversion when the gray scale level obtained by the conversion is in the first gray scale group, while the video signal displays a gray scale level in the first gray scale group which is obtained by diffusing a predetermined value corresponding to the gray scale

level in the second gray scale group when the gray scale level obtained by the conversion is in the second gray scale group.

Other objects and attainments together with a fuller understanding of the invention will become apparent and appreciated by referring to the following description and claims taken in conjunction with the accompanying drawings.

It should be noted that this application is based on the application No. 11-14446 filed in Japan, the contents of which is incorporated herein by reference.

Brief Description of Drawings

Fig. 1 is a typical block diagram of a display apparatus according to a preferred embodiment of the present invention.

Fig. 2A is a typical block diagram of a gray scale limiting and difference diffusion circuit in the display apparatus shown in Fig. 1.

Fig. 2B illustrates the difference accumulation.

Fig. 2C illustrates the difference diffusion.

Fig. 3A is a typical block diagram of a dither circuit in the display apparatus shown in Fig. 1.

Figs. 3B-3C, 3D-3E, and 3F-3G illustrates diffusion pattern for even and odd fields in the display apparatus shown in Fig. 1.

Fig. 4 illustrates the change in pixel gray scale displayed on screen by a display apparatus according to the present invention.

Fig. 5A is a typical block diagram of another limit/difference diffusion circuit.

Fig. 5B illustrates the difference accumulation.

Fig. 5C illustrates the difference diffusion.

Fig. 6 illustrates subfield division of a single image field in a so-called subfield method.

Fig. 7 illustrates the occurrence of pseudo contours in moving pictures.

Fig. 8 illustrates a cause for the occurrence of pseudo contours in moving pictures.

Best Mode for Carrying Out The Invention

A preferred embodiment of a display apparatus according to the present invention is described below with reference to the accompanying figures. It is to be noted that for simplicity the following description is limited to operation with one color only, and it will be obvious to those who skilled in the art that the same method is applicable to a color display with each of the colors, that is, R(red), G(green) and B(blue).

An exemplary display apparatus according to the present invention is shown in Fig. 1. As shown in the figure, this display apparatus comprises an A/D converter 11, a reverse gamma correction circuit 13, a motion detector 15, a gray scale limiting and difference diffusion circuit 17, a dither circuit 19, delay circuit 21, selector 23, image signal-subfield associating circuit 25, subfield processor 27, scanning/sustaining/erasing driver 29, data driver 31, a plasma display panel (PDP) 33, and timing pulse generator 35.

The PDP 33 comprises a plurality of electrodes in a matrix pattern, and can be driven to present two values, that is, on or off. As described above,

a multilevel gray scale display is achieved with this PDP 33 by using a plurality of weighted subfields. The timing pulse generator 35 generates a timing signal based on the horizontal hold signal HD and vertical hold signal VD, and supplies this timing signal (operation clock) to other parts of the display apparatus.

The A/D converter 11 A/D converts a supplied RGB signal. The converted digital RGB signal is then inverse gamma corrected by the reverse gamma correction circuit 13. More specifically, the supplied RGB signal has typically gamma characteristic suitable for presentation on a CRT display. Therefore the reverse gamma correction restores the original gamma characteristic of the uncorrected RGB signal. The A/D-converted RGB signal is then input to the motion detector 15 for moving picture detection. The result of image motion detection is then passed to the selector 23.

After reverse gamma correction, the RGB signal is sent to the delay circuit 21 and to the gray scale limiting and difference diffusion circuit 17. The gray scale limiting and difference diffusion circuit 17 and the dither circuit 19 apply a particular process for suppressing the occurrence of pseudo contours in moving picture elements. More specifically, the gray scale limiting and difference diffusion circuit 17 and dither circuit 19 convert the gray scale levels of pixels in moving picture areas of the supplied image signal that tend to produce pseudo contours to gray scale levels that are unlikely to produce pseudo contours. These circuits are further described more specifically below. The delay circuit 21 delays the reverse gamma corrected RGB signal by enough time required for processing in the circuits 17 and 19.

The selector 23 selects output from the dither circuit 19 based on

the detection result of the motion detector 15 when the motion detector 15 detects motion picture. The selector 23 selects output from the delay circuit 21 when motion picture is not detected. This is because pseudo contours are observed only in moving pictures, and the process for suppressing pseudo contours in the picture signal is applied only to moving pictures.

The video signal selected by the selector 23 is sent to the picture signal-subfield associating circuit 25. This associating circuit 25 converts the video signal to field information comprising a plurality of bits corresponding to subfields. More specifically, this field information is an array of bits indicative of whether a corresponding subfield emits (is on) or not. The subfield processor 27 determines the number of sustain pulses output during the sustain period T3 based on the field information from the associating circuit 25. The scanning/sustaining/erasing driver 29 and data driver 31 control the electrodes of the PDP 33 based on output from the subfield processor 27 to control the on time of each pixel in order to display an image with the desired gray scale levels on PDP 33.

The gray scale limiting and difference diffusion circuit 17 and dither circuit 19 together perform a specific process for suppressing occurrence of pseudo contours in moving pictures of a supplied video signal. This specific process is further described below.

It is to be noted that one field is divided into nine subfields in this preferred embodiment of the present invention. These nine subfields 1 to 9 are respectively weighted with a luminance value of 1, 2, 4, 8, 16, 32, 48, 64 and 80. The weight of each subfield corresponds to the amount of light emitted (luminance) when that subfield is on. A desired gray scale level can be

achieved by selecting an appropriate combination of subfields.

In general, pseudo contours possibly occur at adjacent pixels in moving pictures in the following case. Adjacent pixels emit at approximately equal luminance levels. Further, in a subfield having the greatest weight among the emitting subfields and emitting subfields having weights less than the greatest weight, the distribution of emitting and non-emitting subfields based on the weight is substantially equally separated, and the distribution is substantially opposite in adjacent pixels. For example, using the above-noted subfields 1 to 9 with weights of 1, 2, 4, 8, 16, 32, 48, 64 and 80, pseudo contours occur in such cases as when the luminance of adjacent pixels is 63 (= 01 11111) and 64 (= 10 10000), or 111 (= 011 11111) and 112 (= 101 10000), for example. When such pixels are adjacent, movement in the sight line easily produces a great change in the distribution of the weights between emitting and non-emitting subfields even though there is only a slight change in gray scale, and a pseudo contour easily becomes apparent in the moving picture.

A display apparatus according to the present invention therefore does not use gray scale levels whereby pseudo contours can easily occur for display. Instead, the display apparatus selects only a number of gray scale levels by which pseudo contours is hardly appeared, and uses them for actual display. The gray scale levels thus selected and used for display is hereafter referred to as "display-use gray scale". The gray scale levels of the display-use gray scale compose a display-use gray scale group. The following gray scale levels are selected as the display-use gray scale levels thereby pseudo contours can be prevented and suppressed.

(a) Gradation level that is achieved by using a plurality of emitting

subfields having the emitting subfield with the greatest weight among the emitting subfields required to achieve the desired gray scale level, and all emitting subfields having a weight less than the greatest weight.

In this case there are no non-emitting subfields from the subfield with the lowest weight to the subfield with the highest weight needed to achieve the desired gray scale level. That is, all subfields between these lowest and highest weight subfields emit. Pseudo contours can be suppressed at these gray scale levels because the number of emitting subfields increases stepwise as the gray scale level rises. When there are adjacent pixels with adjacent gray scale levels, there is no great change in the distribution of emitting and non-emitting subfields for the weights, and pseudo contours can therefore be suppressed in moving pictures. Gradation levels satisfying condition (a) are shown in Tables 1 to 5. It is to be noted that in the accompanying tables a value of 1 in the subfield columns indicates that the subfield emits. These gray scales are further indicated by a solid dot (•) in the "display-use gray scale" column. More specifically, gray scale levels of 1, 3, 7, 15, 31, 63, 111, 175, and 255 are these gray scale levels. In addition, gray scale level of 0 is added to the gray scale levels used for display. For example, referring to gray scale level of 31 in Table 1, the emitting subfield with the greatest weight required to display gray scale level of 31 is subfield 5, subfields 1 to 4 are all of the subfields with weight less than subfield 5, and all of these subfields also emit. As a result, gray scale level of 31 satisfies condition of (a).

In addition to the gray scale levels of condition (a), gray scale levels achieved by a plurality of emitting subfields including a greatest-weight subfield and a predetermined number of non-emitting subfields with less weight

than the greatest-weight can also be taken as gray scale levels resistant to pseudo contours. That is , conditions (b) and (c) may be considered as follows.

(b) Gradation levels having one or less of non-emitting subfield in the emitting subfield with the greatest weight required to achieve the gray scale level and all subfields with weights less than the greatest weight.

(c) Gradation levels having two or less of non-emitting subfields in the emitting subfield with the greatest weight required to achieve the gray scale level and all subfields with weights less than the greatest weight.

The number of gray scale levels satisfying conditions (b) and (c) is more than that for condition (a). Therefore more number of gray scale levels can be displayed. There is not a great change between adjacent pixels in the distribution of emitting and non-emitting subfields with gray scale of (b) and (c), as well as gray scale of (a). Examples of gray scale of (b) are shown in Tables 6 to 10, and are similarly indicated by a solid dot (•) in the "display-use gray scale" column. More specifically, in addition to the gray scale levels of (a) shown in Tables 1 to 5, gray scale levels of (b) include levels of 2, 5, 6, 11, 13, 14, 251, 253, 254 and others.

For example, referring to gray scale level 14 in Table 6, the subfield with the greatest weight required to achieve gray scale level 14 is subfield 4; subfields 1 to 3 are all of the subfields with weight less than subfield 4, and these include only one non-emitting subfield (subfield 1). As a result, gray scale level of 14 satisfies condition (b) above.

A gray scale level exemplary of condition (c) above is gray scale level of 28. That is, the subfield with the greatest weight required to achieve gray scale level of 28 is subfield 5; subfields 1 to 4 are all of the subfields with

weight less than subfield 4, and these include only two non-emitting subfields (subfield 1 and subfield 2). As a result, gray scale level of 28 satisfies condition (c) above.

By thus using for display only the gray scale levels selected above, higher order subfields and lower order subfields do not switch between emitting and non-emitting states at adjacent pixels and the occurrence of pseudo contours in moving pictures can be suppressed.

In cases (a) and (c) above, it may not be necessary to consider a specific lower order subfield. Because low order subfields have little weight, and therefore have relatively little effect on pseudo contours in moving pictures. For example, it is possible to select as gray scale levels of (a), levels for which all but the lowest order subfield (subfield 1) emit. It is alternatively possible to further exclude the second (subfield 2) from lowest order subfield 1, or the third (subfield 3) from lowest order subfield 1.

Gray scale levels each of which is in the middle of the display-use gray scale levels is further defined as "dithered gray scale " in this preferred embodiment of the present invention. Gray scale levels of the dithered gray scale compose a dithered gray scale group. These gray scales are indicated by a solid dot (•) in the "dithered gray scale" column in Tables 1 to 10.

For example, the dithered gray scale in Tables 1 to 5 are levels of 2, 5, 11, 23, 47, 87, 143, and 215. The distance between a dithered gray scale level and the adjacent display-use gray scale level is the dither value. For example, the dither value at dithered gray scale level of 11 in Table 1 is 4; at dithered gray scale level of 23, this value is 8. This dither value is not used directly for display purposes, but is used to express a dithered gray scale level

by diffusing the dithered gray scale to the display-use gray scale levels above and below the dithered gray scale level based on the dither value.

A display apparatus according to the present invention is further described using the display-use gray scales and dithered gray scales shown in Tables 1 to 5. The display apparatus therefore displays at the luminance of gray scale levels of 0, 1, 3, 7, 15, 31, 63, 111, 175, and 255 only. Note, further, that dithered gray scale and display-use gray scale are both referred to as "converted gray scale."

The gray scale limiting and difference diffusion circuit 17 stores converted gray scale information in a gray scale table (described below). Using this gray scale table, the gray scale limiting and difference diffusion circuit 17 converts gray scale level of the pixel of the video signal after reverse gamma correction to a converted gray scale level. When the converted gray scale from the gray scale limiting and difference diffusion circuit 17 is one of display-use gray scale, the dither circuit 19 generates a video signal for presenting that display-use gray scale. When the converted gray scale level is one of dithered gray scale levels, the dither circuit 19 applies a predetermined diffusion process (described below) based on the dither value of that dithered gray scale, and generates a video signal for displaying the dithered gray scale using the display-use gray scale.

A typical configuration of an exemplary gray scale limiting and difference diffusion circuit 17 is shown in Fig. 2A. This gray scale limiting and difference diffusion circuit 17 comprises an adder 51, gray scale table 53, dither table 55, and difference diffusion processor 60. The operation of a gray scale limiting and difference diffusion circuit 17 thus comprised is described next

below.

When a video signal containing pixel gray scale information is sent from the reverse gamma correction circuit 13 to gray scale limiting and difference diffusion circuit 17, adder 51 adds the original pixel gray scale based on the video signal and a difference e diffused from the pixels processed before that pixel, and outputs the result of the addition to the gray scale table 53 and difference diffusion processor 60.

The gray scale table 53 stores information relating to the above-noted converted gray scale levels, and converts a supplied gray scale level to a corresponding converted gray scale level. That is, the gray scale table 53 selects one converted gray scale level corresponding to the gray scale level determined by adding diffusion difference e to the original pixel gray scale, and outputs the selected converted gray scale level to the difference diffusion processor 60.

This gray scale table 53 contains in this exemplary embodiment the information relating to the display-use gray scales and dithered gray scales shown in Tables 1 to 5. Selected as output from gray scale table 53 is the greater one of the highest display-use gray scale within the gray scale range of the supplied signal and the dithered gray scale. For example, when the supplied gray scale level is 20, display-use gray scale level of 15 is selected. When the supplied gray scale level is 25, display-use gray scale level of 23 is selected.

The difference diffusion processor 60 performs a process for diffusing the difference between the converted gray scales obtained by gray scale table 53 and the gray scale level before conversion, to the pixels

surrounding the pixel being processed. This is referred to below as a difference diffusion process. By applying this difference diffusion process to the entire image, the overall gray scale range of the screen image will be maintained, and the overall image will appear to the eye to be displayed with greater fidelity to the original luminance values of the individual pixels. It is therefore possible to display a clearer, sharper, higher quality image.

The difference diffusion processor 60 comprises subtracter 61, delay circuits 63, 65, 67 and 69, multipliers 71, 73, 75 and 77, and adder 79.

In the difference diffusion processor 60, by subtracter 61, the gray scale level obtained by adding difference e to the original pixel gray scale level is subtracted by the converted gray scale level from the gray scale level to obtain the difference e'. The obtained difference e' is passed to delay circuits 63 and 69.

Delay circuit 63 delays the input signal by a period equal to one line minus one pixel and output the delayed signal. Delay circuits 65, 67 and 69 delay the respective input signals by one pixel and output the delayed signal. Delay circuit 63 therefore outputs difference e' for the pixel immediately following the pixel currently being processed but in the preceding line. Delay circuit 65 outputs difference e' for the pixel currently being processed but in the preceding line. Delay circuit 67 outputs difference e' for the pixel immediately before the pixel currently being processed but in the preceding line. Delay circuit 69 outputs difference e' for the pixel immediately before the pixel currently being processed.

The difference values output from delay circuits 69, 63, 65 and 67 are then multiplied by predetermined coefficients k0, k1, k2, and k3 by

multipliers 71, 73, 75 and 77. The coefficients k0, k1, k2, and k3 are desirably set so that k0 + k1 + k2 + k3 = 1. Adder 79 then adds the outputs from multipliers 71, 73, 75, and 77, and outputs the sum as the difference e for the pixel being processed. In other words, difference diffusion processor 60 diffuses the difference e' between the converted gray scale level and the gray scale level obtained by adding difference e to the original pixel gray scale level, to adjacent pixels at a specific diffusion ratio k0 to k3 as shown in Fig. 2C. In addition, the diffusion difference e for a certain pixel is obtained by adding the difference diffused from adjacent pixels as shown in Fig. 2B.

The converted gray scale level obtained by gray scale table 53 is also output to dither table 55. This dither table 55 has information correlating the dithered gray scale levels and dither values shown in Tables 1 to 5. The dither table 55 thus outputs the dither value corresponding to a particular dithered gray scale level when the converted gray scale level supplied from the gray scale table 53 is a dithered gray scale; when not a dithered gray scale, that is, is a display-use gray scale, the dither table 55 outputs a dither value of 0. For example, when the converted gray scale level supplied from the gray scale table 53 is 23, the dither table 55 outputs a dither value of 8 (see Table 1).

When receiving the gray scale level for a particular pixel, the gray scale limiting and difference diffusion circuit 17 thus selects a converted gray scale level appropriate for expressing the gray scale level of the pixel based on a gray scale level obtained by adding a diffusion difference value for that pixel to the gray scale level of the pixel. The gray scale limiting and difference diffusion circuit 17 then outputs a dither value for that converted gray scale level. The dither values and video signal containing converted gray scale levels are

then output from the gray scale limiting and difference diffusion circuit 17 to the dither circuit 19.

Next, this dither circuit 19 is described. The dither circuit 19 performs a diffusing process (dither diffusing process) when the converted gray scale level obtained by the gray scale limiting and difference diffusion circuit 17 is not a display-use gray scale, that is, is a dithered gray scale. This diffusing process diffuses a gray scale level in the dithered gray scale by dither value to obtain a gray scale level in the display-use gray scale to be displayed.

More specifically, when the input gray scale level is the dithered gray scale, the dither circuit 19 generates a video signal in which the display-use gray scale levels offset the dither value from the dithered gray scale level are alternately displayed in even and odd fields of one picture field. The desired dithered gray scale level is thus achieved on screen by time-averaging the display of appropriately selected display-use gray scales levels. For example, to display gray scale level of 23 which is a dithered gray scale with a dither value of 8, one of even and odd field is displayed at gray scale level of 15 (= 23 - 8), and the other of even and odd field is displayed at gray scale level of 31 (= 23 + 8).

Dithering (gray scale diffusion) is changed pixel by pixel as shown in Figs. 3B and 3C in this diffusing process. That is, whether dither values are added to or subtracted from a adjacent pixel depends on whether an odd or even field is being processed with the dither patterns of the odd and even fields being mutually opposite. Adding and subtracting dither values are also opposite at the same pixel position in even and odd fields. Adding and subtracting dither values can also be inverted in this diffusing process by line as shown in Figs.

3D and 3E, or by field as shown in Figs. 3F and 3G. It is to be noted that in each case, that is, Figs. 3B and 3C, Figs.3D and 3E, and Figs.3F and 3G, dithering results in a zero sum in corresponding even and odd fields.

Using dithered gray scale in addition to the above-noted display-use gray scales as converted gray scales can be expected to yield the following benefits.

Let us assume that the gray scale level changes from 111 to 175 from the left to right sides of the screen as shown in Fig. 4. Only gray scale level of 111 appears at the left edge of the screen, and only gray scale level of 175 is at the right edge. A gray scale level of 143 (dithered gray scale) is in the middle, where gray scale levels of 111 and 175 can be alternately switched to be displayed equally. The ratio at which levels of 111 and 175 appear from the middle of the screen to both edges changes continuously. In other words, when a dithered gray scale (which is level of 143 in this example) which in the middle of display-use gray scale levels is achieved, the display-use gray scales appears precisely half of the total presentation time. It is therefore possible to display the middle gray scale more clearly compared with using only difference diffusion and no dithered gray scales.

The configuration of a typical dither circuit 19 is shown in Fig. 3A. The dither circuit 19 comprises an adder 91, subtracter 93, selector 95, and switching pattern generator 97.

The adder 91 adds the dither value to a converted gray scale. The subtracter 93 subtracts the dither value from the converted gray scale. The switching pattern generator 97 outputs a control signal determining whether the dither value is added or subtracted for a given pixel based on the pattern shown

in Fig. 3B or 3C. The selector 95 selects the output from the adder 91 or subtracter 93 based on the control signal to pass.

When the converted gray scale output from the gray scale limiting and difference diffusion circuit 17 is a display-use gray scale, the dither value is output as 0. The dither circuit 19 therefore has no effect on gray scale whether it adds or subtracts.

A display apparatus according to this preferred embodiment of the present invention thus converts the original gray scale level of each pixel to a display-use gray scale that is relatively resistant to pseudo contours appearing in moving pictures. By using only these selected display gray scales to achieve a multilevel gray scale display, the occurrence of pseudo contours in moving pictures can thus be suppressed.

As described above, however, the gray scale limiting and difference diffusion circuit 17 sequentially receives the video signal for each pixel and processes pixels one by one in synchronous with a predetermined operating clock. The operating clock is typically set to the time required to process one pixel. With a screen contains 852 x 480 pixels, for example, one clock of the operating clock runs at approximately 40.7 ns, that is, 1 second / 60 frames / (852 x 480 pixels). Processing one pixel must be completed by the time the next pixel is received. For example, the gray scale difference to be diffused for the next pixel must be calculated within a period of one clock cycle. This means that the gray scale table 53 of the gray scale limiting and difference diffusion circuit 17 must convert the gray scale of the pixel being processed to the particular converted gray scale, and the difference diffusion processor 60 must complete the diffusing operation, within one clock cycle.

Processing by the gray scale table 53 and the subtracter 61 of the difference diffusion processor 60 alone, however, requires approximately 34.5 μs, an extremely long time relative to the clock cycle. Particularly the operation in the subtracter 61 takes much time. To complete these operations within one clock cycle using the circuit design shown in Fig. 2A, it is therefore necessary to generate and supply to the difference diffusion processor 60 a high speed clock that is provided extra. This necessitates complex circuitry, increases the overall circuit scale, and leads to increased cost. A preferred embodiment of the gray scale limiting and difference diffusion circuit 17 that solves this problem is described below.

Fig. 5A shows the preferred structure of the gray scale limiting and difference diffusion circuit 17. It is to be noted that like parts in Fig. 2A and Fig. 5A are identified by like reference numeral. The gray scale limiting and difference diffusion circuit 17 shown in Fig. 5A differs from that shown in Fig. 2A in the design of the difference diffusion processor 60'.

The time required for diffusing to the next pixel, that is, in the horizontal direction, is particularly short. The purpose of this difference diffusion processor 60', therefore, is to accelerate diffusing operation calculations in the horizontal direction.

In addition to the parts shown in Fig. 2A, the difference diffusion processor 60' in Fig. 5A further comprises a low bits splitting circuit 81 and another subtracter 62. The low bits splitting circuit 81 receives output from the adder 51. The delay circuit 69 receives output e' from the low bits splitting circuit 81. The subtracter 62 is disposed between the subtracter 61 and the delay circuit 63 to receive output from subtracter 61 and output e' from low bits

splitting circuit 81.

A difference diffusion processor 60' thus comprised uses a predetermined low bits in the gray scale data from the adder 51 as the difference e' to be diffused to the next pixel to be processed, that is, the pixel immediately following the pixel currently being processed. More specifically, the low bits splitting circuit 81 separates the lower 4 bits from the gray scale data (which is normally 8 bits) received from adder 51 as difference e'. The low bits splitting circuit 81 can easily separate predetermined low bits from the supplied data with processing being completed in an extremely short time. Processing can therefore be easily completed within one clock cycle.

The difference e" to be diffused in the vertical direction, that is, to the same pixel in the next line, can be obtained by the subtracter 61 obtaining the difference between the gray scale level obtained by adding difference e to the original pixel gray scale level and the converted gray scale level obtained from gray scale table 53, and subtracter 62 removing from this difference the difference e' already diffused in the horizontal direction. There is no problems to obtain the difference e" to be diffused in the vertical direction by operating (subtracting) the gray scale, because there is a time margin or delay of approximately one line until the diffusion value is used.

This difference diffusion processor 60' thus takes lower bits obtained from the gray scale data (typically 8 bits) as the difference to be diffused to the next pixel in the horizontal direction. The difference diffusion processor 60' also takes, as the diffused difference in vertical direction, value obtained by subtracting the horizontal diffusion value from the difference between the original pixel gray scale level including difference e and the gray

scale level obtained from gray scale table 53. The processor 60' performs difference diffusion process using those difference values. It is therefore possible using a simple circuit design to complete the diffusing operation in a short time within one clock cycle.

As will be known from the preceding description of preferred embodiments of the present invention, a display apparatus according to the present invention uses only specific gray scale levels selected from among the range of gray scale levels that can be expressed by the above-described subfield method. These specific gray scale levels are gray scales at which pseudo contours in moving pictures do not easily occur. More specifically, these gray scale levels include gray scale levels of (a) achieved using a plurality of emitting subfields including the emitting subfield with the greatest weight required to achieve the gray scale level and all subfields with a weight less than this greatest weight, and gray scale levels of (b) achieved using a plurality of emitting subfields including the emitting subfield with the greatest weight required to achieve the gray scale level and at most one non-emitting subfield with less weight than the greatest-weight.

In other words, a display apparatus according to the present invention uses for video display only gray scale levels that are unlikely to produce undesirable pseudo contours in moving pictures. As a result, the occurrence of such pseudo contours can be suppressed. When converting the original gray scale level of each pixel in the picture to one of these gray scale levels used for display, a display apparatus according to the present invention preferably converts to one of these display gray scale levels or to an intermediate gray scale level between gray scale levels. By thus including such

intermediate gray scale levels in the gray scale conversion process, smoother transitions between gray scale levels can be achieved.

It is further preferable to diffuse to surrounding pixels any difference that occurs in the conversion of the original pixel gray scale levels to a selected display-use gray scale level. This operation retains the original pixel gray scale level within the overall image.

The diffusion or dither value applied in the horizontal direction can also be obtained by simply detecting specific low bits in the pixel gray scale data. The time required to obtain this diffusion information can thus be shortened, and a simple circuit configuration can be used for the dithering operation.

Although the present invention has been described in connection with specified embodiments thereof, many other modifications, corrections and applications are apparent to those skilled in the art. Therefore, the present invention is not limited by the disclosure provided herein but limited only to the scope of the appended claims.

TABLE 1

Example of Gray Scale Display with 9 Subfields

(Display-use Gray Scale in which all subfields lighter than the emittig heaviest subfield are emitted)

Gray Scale Level	Subfield 1 Weight (1)	2 (2)	3 (4)	4 (8)	5 (16)	6 (32)	7 (48)	8 (64)	9 (80)	Display-use Gray Scale	Ditherd Gray Scale	Dither Value
0										●		
1	1									●		
2		1									●	1
3	1	1								●		
4			1									
5	1		1								●	2
6		1	1									
7	1	1	1							●		
8				1								
9	1			1								
10		1		1								
11	1	1		1							●	4
12			1	1								
13	1		1	1								
14		1	1	1								
15	1	1	1	1						●		
16					1							
17	1				1							
18		1			1							
19	1	1			1							
20			1		1							
21	1		1		1							
22		1	1		1							
23	1	1	1		1						●	8
24				1	1							
25	1			1	1							
26		1		1	1							
27	1	1		1	1							
28			1	1	1							
29	1		1	1	1							
30		1	1	1	1							
31	1	1	1	1	1					●		
32						1						
33	1					1						
34		1				1						
35	1	1				1						
36			1			1						
37	1		1			1						
38		1	1			1						
39	1	1	1			1						
40				1		1						
41	1			1		1						
42		1		1		1						
43	1	1		1		1						
44			1	1		1						
45	1		1	1		1						
46		1	1	1		1						
47	1	1	1	1		1					●	16
48					1	1						

TABLE 2

Gray Scale Level	Subfield 1 Weight (1)	2 (2)	3 (4)	4 (8)	5 (16)	6 (32)	7 (48)	8 (64)	9 (80)	Display-use Gray Scale	Ditherd Gray Scale	Dither Value
49	1				1	1						
50		1			1	1						
51	1	1			1	1						
52			1		1	1						
53	1		1		1	1						
54		1	1		1	1						
55	1	1	1		1	1						
56				1	1	1						
57	1			1	1	1						
58		1		1	1	1						
59	1	1		1	1	1						
60			1	1	1	1						
61	1		1	1	1	1						
62		1	1	1	1	1						
63	1	1	1	1	1	1				●		
64					1		1					
65	1				1		1					
66		1			1		1					
67	1	1			1		1					
68			1		1		1					
69	1		1		1		1					
70		1	1		1		1					
71	1	1	1		1		1					
72				1	1		1					
73	1			1	1		1					
74		1		1	1		1					
75	1	1		1	1		1					
76			1	1	1		1					
77	1		1	1	1		1					
78		1	1	1	1		1					
79	1	1	1	1	1		1					
80						1	1					
81	1					1	1					
82		1				1	1					
83	1	1				1	1					
84			1			1	1					
85	1		1			1	1					
86		1	1			1	1				●	24
87	1	1	1			1	1					
88				1		1	1					
89	1			1		1	1					
90		1		1		1	1					
91	1	1		1		1	1					
92			1	1		1	1					
93	1		1	1		1	1					
94		1	1	1		1	1					
95	1	1	1	1		1	1					
96					1	1	1					
97	1				1	1	1					
98		1			1	1	1					
99	1	1			1	1	1					
100			1		1	1	1					

TABLE 3

Gray Scale Level	Subfield									Display-use Gray Scale	Ditherd Gray Scale	Dither Value
	1	2	3	4	5	6	7	8	9			
	Weight (1)	(2)	(4)	(8)	(16)	(32)	(48)	(64)	(80)			
101	1		1		1	1	1					
102		1	1		1	1	1					
103	1	1	1		1	1	1					
104				1	1	1	1					
105	1			1	1	1	1					
106		1		1	1	1	1					
107	1	1		1	1	1	1					
108			1	1	1	1	1					
109	1		1	1	1	1	1					
110		1	1	1	1	1	1					
111	1	1	1	1	1	1	1			●		
112					1	1		1				
113	1				1	1		1				
114		1			1	1		1				
115	1	1			1	1		1				
116			1		1	1		1				
117	1		1		1	1		1				
118		1	1		1	1		1				
119	1	1	1		1	1		1				
120				1	1	1		1				
121	1			1	1	1		1				
122		1		1	1	1		1				
123	1	1		1	1	1		1				
124			1	1	1	1		1				
125	1		1	1	1	1		1				
126		1	1	1	1	1		1				
127	1	1	1	1	1	1		1				
128					1		1	1				
129	1				1		1	1				
130		1			1		1	1				
131	1	1			1		1	1				
132			1		1		1	1				
133	1		1		1		1	1				
134		1	1		1		1	1				
135	1	1	1		1		1	1				
136				1	1		1	1				
137	1			1	1		1	1				
138		1		1	1		1	1				
139	1	1		1	1		1	1				
140			1	1	1		1	1				
141	1		1	1	1		1	1				
142		1	1	1	1		1	1				
143	1	1	1	1	1		1	1			●	32
144						1	1	1				
145	1					1	1	1				
146		1				1	1	1				
147	1	1				1	1	1				
148			1			1	1	1				
149	1		1			1	1	1				
150		1	1			1	1	1				
151	1	1	1			1	1	1				
152				1		1	1	1				

TABLE 4

Gray Scale Level	Subfield									Display-use Gray Scale	Ditherd Gray Scale	Dither Value
	1	2	3	4	5	6	7	8	9			
	Weight (1)	(2)	(4)	(8)	(16)	(32)	(48)	(64)	(80)			
153	1			1		1	1	1				
154		1		1		1	1	1				
155	1	1		1		1	1	1				
156			1	1		1	1	1				
157	1		1	1		1	1	1				
158		1	1	1		1	1	1				
159	1	1	1	1		1	1	1				
160					1	1	1	1				
161	1				1	1	1	1				
162		1			1	1	1	1				
163	1	1			1	1	1	1				
164			1		1	1	1	1				
165	1		1		1	1	1	1				
166		1	1		1	1	1	1				
167	1	1	1		1	1	1	1				
168				1	1	1	1	1				
169	1			1	1	1	1	1				
170		1		1	1	1	1	1				
171	1	1		1	1	1	1	1				
172			1	1	1	1	1	1				
173	1		1	1	1	1	1	1				
174		1	1	1	1	1	1	1				
175	1	1	1	1	1	1	1	1				
176					1	1	1		1			
177	1				1	1	1		1			
178		1			1	1	1		1			
179	1	1			1	1	1		1			
180			1		1	1	1		1			
181	1		1		1	1	1		1			
182		1	1		1	1	1		1			
183	1	1	1		1	1	1		1			
184				1	1	1	1		1			
185	1			1	1	1	1		1			
186		1		1	1	1	1		1			
187	1	1		1	1	1	1		1			
188			1	1	1	1	1		1			
189	1		1	1	1	1	1		1			
190		1	1	1	1	1	1		1			
191	1	1	1	1	1	1	1		1			
192					1	1		1	1			
193	1				1	1		1	1			
194		1			1	1		1	1			
195	1	1			1	1		1	1			
196			1		1	1		1	1			
197	1		1		1	1		1	1			
198		1	1		1	1		1	1			
199	1	1	1		1	1		1	1			
200				1	1	1		1	1			
201	1			1	1	1		1	1			
202		1		1	1	1		1	1			
203	1	1		1	1	1		1	1			
204			1	1	1	1		1	1			

TABLE 5

Gray Scale Level	Subfield									Display-use Gray Scale	Ditherd Gray Scale	Dither Value
	1	2	3	4	5	6	7	8	9			
	Weight (1)	(2)	(4)	(8)	(16)	(32)	(48)	(64)	(80)			
205	1		1	1	1	1		1	1			
206		1	1	1	1	1		1	1			
207	1	1	1	1	1	1		1	1			
208					1		1	1	1			
209	1				1		1	1	1			
210		1			1		1	1	1			
211	1	1			1		1	1	1			
212			1		1		1	1	1			
213	1		1		1		1	1	1			
214		1	1		1		1	1	1			
215	1	1	1		1		1	1	1		●	40
216				1	1		1	1	1			
217	1			1	1		1	1	1			
218		1		1	1		1	1	1			
219	1	1		1	1		1	1	1			
220			1	1	1		1	1	1			
221	1		1	1	1		1	1	1			
222		1	1	1	1		1	1	1			
223	1	1	1	1	1		1	1	1			
224						1	1	1	1			
225	1					1	1	1	1			
226		1				1	1	1	1			
227	1	1				1	1	1	1			
228			1			1	1	1	1			
229	1		1			1	1	1	1			
230		1	1			1	1	1	1			
231	1	1	1			1	1	1	1			
232				1		1	1	1	1			
233	1			1		1	1	1	1			
234		1		1		1	1	1	1			
235	1	1		1		1	1	1	1			
236			1	1		1	1	1	1			
237	1		1	1		1	1	1	1			
238		1	1	1		1	1	1	1			
239	1	1	1	1		1	1	1	1			
240					1	1	1	1	1			
241	1				1	1	1	1	1			
242		1			1	1	1	1	1			
243	1	1			1	1	1	1	1			
244			1		1	1	1	1	1			
245	1		1		1	1	1	1	1			
246		1	1		1	1	1	1	1			
247	1	1	1		1	1	1	1	1			
248				1	1	1	1	1	1			
249	1			1	1	1	1	1	1			
250		1		1	1	1	1	1	1			
251	1	1		1	1	1	1	1	1			
252			1	1	1	1	1	1	1			
253	1		1	1	1	1	1	1	1			
254		1	1	1	1	1	1	1	1			
255	1	1	1	1	1	1	1	1	1	●		

TABLE 6

Example of Gray Scale Display with 9 Subfields

(Display-use Gray Scale in which one or less of subfields lighter than the emittig heaviest subfield is not emitted)

Gray Scale Level	Subfield									Display-use Gray Scale	Ditherd Gray Scale	Dither Value
	1	2	3	4	5	6	7	8	9			
	Weight (1)	(2)	(4)	(8)	(16)	(32)	(48)	(64)	(80)			
0										●		
1	1									●		
2		1								●		
3	1	1								●		
4			1								●	1
5	1		1							●		
6		1	1							●		
7	1	1	1							●		
8				1								
9	1			1							●	2
10		1		1								
11	1	1		1						●		
12			1	1							●	1
13	1		1	1						●		
14		1	1	1						●		
15	1	1	1	1						●		
16					1							
17	1				1							
18		1			1							
19	1	1			1						●	4
20			1		1							
21	1		1		1							
22		1	1		1							
23	1	1	1		1					●		
24				1	1							
25	1			1	1						●	2
26		1		1	1							
27	1	1		1	1					●		
28			1	1	1						●	1
29	1		1	1	1					●		
30		1	1	1	1					●		
31	1	1	1	1	1					●		
32						1						
33	1					1						
34		1				1						
35	1	1				1						
36			1			1						
37	1		1			1						
38		1	1			1						
39	1	1	1			1					●	8
40				1		1						
41	1			1		1						
42		1		1		1						
43	1	1		1		1						
44			1	1		1						
45	1		1	1		1						
46		1	1	1		1						
47	1	1	1	1		1				●		
48					1	1						

TABLE 7

Gray Scale Level	Subfield									Display-use Gray Scale	Ditherd Gray Scale	Dither Value
	1	2	3	4	5	6	7	8	9			
	Weight (1)	(2)	(4)	(8)	(16)	(32)	(48)	(64)	(80)			
49	1				1	1						
50		1			1	1						
51	1	1			1	1					●	4
52			1		1	1						
53	1		1		1	1						
54		1	1		1	1						
55	1	1	1		1	1				●		
56				1	1	1						
57	1			1	1	1					●	2
58		1		1	1	1						
59	1	1		1	1	1				●		
60			1	1	1	1					●	1
61	1		1	1	1	1				●		
62		1	1	1	1	1				●		
63	1	1	1	1	1	1				●		
64					1		1					
65	1				1		1					
66		1			1		1					
67	1	1			1		1					
68			1		1		1					
69	1		1		1		1					
70		1	1		1		1					
71	1	1	1		1		1				●	8
72				1	1		1					
73	1			1	1		1					
74		1		1	1		1					
75	1	1		1	1		1					
76			1	1	1		1					
77	1		1	1	1		1					
78		1	1	1	1		1					
79	1	1	1	1	1		1			●		
80						1	1					
81	1					1	1					
82		1				1	1					
83	1	1				1	1					
84			1			1	1					
85	1		1			1	1					
86		1	1			1	1					
87	1	1	1			1	1				●	8
88				1		1	1					
89	1			1		1	1					
90		1		1		1	1					
91	1	1		1		1	1					
92			1	1		1	1					
93	1		1	1		1	1					
94		1	1	1		1	1					
95	1	1	1	1		1	1			●		
96					1	1	1					
97	1				1	1	1					
98		1			1	1	1					
99	1	1			1	1	1				●	4
100			1		1	1	1					

TABLE 8

Gray Scale Level	Subfield									Display-use Gray Scale	Ditherd Gray Scale	Dither Value
	1	2	3	4	5	6	7	8	9			
	Weight (1)	(2)	(4)	(8)	(16)	(32)	(48)	(64)	(80)			
101	1		1		1	1	1					
102		1	1		1	1	1					
103	1	1	1		1	1	1			●		
104				1	1	1	1					
105	1			1	1	1	1				●	2
106		1		1	1	1	1					
107	1	1		1	1	1	1			●		
108			1	1	1	1	1				●	1
109	1		1	1	1	1	1			●		
110		1	1	1	1	1	1			●		
111	1	1	1	1	1	1	1			●		
112					1	1		1				
113	1				1	1		1				
114		1			1	1		1				
115	1	1			1	1		1				
116			1		1	1		1				
117	1		1		1	1		1				
118		1	1		1	1		1				
119	1	1	1		1	1		1			●	8
120				1	1	1		1				
121	1			1	1	1		1				
122		1		1	1	1		1				
123	1	1		1	1	1		1				
124			1	1	1	1		1				
125	1		1	1	1	1		1				
126		1	1	1	1	1		1				
127	1	1	1	1	1	1		1		●		
128					1		1	1				
129	1				1		1	1				
130		1			1		1	1				
131	1	1			1		1	1				
132			1		1		1	1				
133	1		1		1		1	1				
134		1	1		1		1	1				
135	1	1	1		1		1	1			●	8
136				1	1		1	1				
137	1			1	1		1	1				
138		1		1	1		1	1				
139	1	1		1	1		1	1				
140			1	1	1		1	1				
141	1		1	1	1		1	1				
142		1	1	1	1		1	1				
143	1	1	1	1	1		1	1		●		
144						1	1	1				
145	1					1	1	1				
146		1				1	1	1				
147	1	1				1	1	1				
148			1			1	1	1				
149	1		1			1	1	1				
150		1	1			1	1	1				
151	1	1	1			1	1	1			●	8
152				1		1	1	1				

TABLE 9

Gray Scale Level	Subfield									Display-use Gray Scale	Ditherd Gray Scale	Dither Value
	1	2	3	4	5	6	7	8	9			
	Weight (1)	(2)	(4)	(8)	(16)	(32)	(48)	(64)	(80)			
153	1			1		1	1	1				
154		1		1		1	1	1				
155	1	1		1		1	1	1				
156			1	1		1	1	1				
157	1		1	1		1	1	1				
158		1	1	1		1	1	1				
159	1	1	1	1		1	1	1		●		
160					1	1	1	1				
161	1				1	1	1	1				
162		1			1	1	1	1				
163	1	1			1	1	1	1			●	4
164			1		1	1	1	1				
165	1		1		1	1	1	1				
166		1	1		1	1	1	1				
167	1	1	1		1	1	1	1		●		
168				1	1	1	1	1				
169	1			1	1	1	1	1			●	2
170		1		1	1	1	1	1				
171	1	1		1	1	1	1	1		●		
172			1	1	1	1	1	1			●	1
173	1		1	1	1	1	1	1		●		
174		1	1	1	1	1	1	1		●		
175	1	1	1	1	1	1	1	1		●		
176					1	1	1		1			
177	1				1	1	1		1			
178		1			1	1	1		1			
179	1	1			1	1	1		1			
180			1		1	1	1		1			
181	1		1		1	1	1		1			
182		1	1		1	1	1		1			
183	1	1	1		1	1	1		1		●	8
184				1	1	1	1		1			
185	1			1	1	1	1		1			
186		1		1	1	1	1		1			
187	1	1		1	1	1	1		1			
188			1	1	1	1	1		1			
189	1		1	1	1	1	1		1			
190		1	1	1	1	1	1		1			
191	1	1	1	1	1	1	1		1	●		
192					1	1		1	1			
193	1				1	1		1	1			
194		1			1	1		1	1			
195	1	1			1	1		1	1			
196			1		1	1		1	1			
197	1		1		1	1		1	1			
198		1	1		1	1		1	1			
199	1	1	1		1	1		1	1		●	8
200				1	1	1		1	1			
201	1			1	1	1		1	1			
202		1		1	1	1		1	1			
203	1	1		1	1	1		1	1			
204			1	1	1	1		1	1			

TABLE 10

Gray Scale Level	Subfield									Display-use Gray Scale	Ditherd Gray Scale	Dither Value
	1	2	3	4	5	6	7	8	9			
	Weight (1)	(2)	(4)	(8)	(16)	(32)	(48)	(64)	(80)			
205	1		1	1	1	1		1	1			
206		1	1	1	1	1		1	1			
207	1	1	1	1	1	1		1	1	●		
208					1		1	1	1			
209	1				1		1	1	1			
210		1			1		1	1	1			
211	1	1			1		1	1	1			
212			1		1		1	1	1			
213	1		1		1		1	1	1			
214		1	1		1		1	1	1			
215	1	1	1		1		1	1	1		●	8
216				1	1		1	1	1			
217	1			1	1		1	1	1			
218		1		1	1		1	1	1			
219	1	1		1	1		1	1	1			
220			1	1	1		1	1	1			
221	1		1	1	1		1	1	1			
222		1	1	1	1		1	1	1			
223	1	1	1	1	1		1	1	1	●		
224						1	1	1	1			
225	1					1	1	1	1			
226		1				1	1	1	1			
227	1	1				1	1	1	1			
228			1			1	1	1	1			
229	1		1			1	1	1	1			
230		1	1			1	1	1	1			
231	1	1	1			1	1	1	1		●	8
232				1		1	1	1	1			
233	1			1		1	1	1	1			
234		1		1		1	1	1	1			
235	1	1		1		1	1	1	1			
236			1	1		1	1	1	1			
237	1		1	1		1	1	1	1			
238		1	1	1		1	1	1	1			
239	1	1	1	1		1	1	1	1	●		
240					1	1	1	1	1			
241	1				1	1	1	1	1			
242		1			1	1	1	1	1			
243	1	1			1	1	1	1	1		●	4
244			1		1	1	1	1	1			
245	1		1		1	1	1	1	1			
246		1	1		1	1	1	1	1			
247	1	1	1		1	1	1	1	1	●		
248				1	1	1	1	1	1			
249	1			1	1	1	1	1	1		●	2
250		1		1	1	1	1	1	1			
251	1	1		1	1	1	1	1	1	●		
252			1	1	1	1	1	1	1		●	1
253	1		1	1	1	1	1	1	1	●		
254		1	1	1	1	1	1	1	1	●		
255	1	1	1	1	1	1	1	1	1	●		

CLAIMS

1. A display apparatus for performing gray scale display by dividing one field of picture into a plurality of weighted subfields and by controlling each subfield to emit or not emit based on the gray scale level of pixel in the picture, said apparatus comprising:

a conversion unit for selectively converting a gray scale level of the pixel to one gray scale level in a first gray scale group or one gray scale level in a second gray scale group, said first gray scale group including a plurality of gray scale levels to be used for actual display, the gray scale level in the first gray scale group being expressed by the combination of the subfields, said second gray scale group including a plurality of gray scale levels each of which is in the middle of the gray scale levels in the first gray scale group; and

a first diffusion unit for generating video signal, said video signal displaying a gray scale level obtained by the conversion unit when the gray scale level obtained by the conversion unit is in the first gray scale group, or a gray scale level in the first gray scale group which is obtained by diffusing a predetermined value corresponding to the gray scale level in the second gray scale group when the gray scale level obtained by the conversion unit is in the second gray scale group.

2. The apparatus according to claim 1, wherein the first gray scale group includes gray scale levels each of which is achieved by subfields in which there is no non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level.

3. The apparatus according to claim 1, wherein the first gray scale group includes gray scale levels each of which is achieved by subfields in which there is at most one of non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level.

4. The apparatus according to claim 1, wherein the first gray scale group includes gray scale levels each of which is achieved by subfields in which there is at most two of non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level.

5. The apparatus according to claim2, wherein said non-emitting subfield excludes a subfield having the minimum weight.

6. The apparatus according to claim3, wherein said non-emitting subfield excludes a subfield having the minimum weight.

7. The apparatus according to claim4, wherein said non-emitting subfield excludes a subfield having the minimum weight.

8. The apparatus according to claim2, wherein said non-emitting subfield excludes a subfield having the minimum weight and a subfield having the next succeeding minimum weight.

9. The apparatus according to claim3, wherein said non-emitting subfield excludes a subfield having the minimum weight and a subfield having the next succeeding minimum weight.

10. The apparatus according to claim4, wherein said non-emitting subfield excludes a subfield having the minimum weight and a subfield having the next succeeding minimum weight.

11. The apparatus according to claim 2, wherein said non-emitting subfield excludes a subfield having the minimum weight, a subfield having the next succeeding minimum weight and a subfield having the third succeeding minimum weight.

12. The apparatus according to claim 3, wherein said non-emitting subfield excludes a subfield having the minimum weight, a subfield having the next succeeding minimum weight and a subfield having the third succeeding minimum weight.

13. The apparatus according to claim4, wherein said non-emitting subfield excludes a subfield having the minimum weight, a subfield having the next succeeding minimum weight and a subfield having the third succeeding minimum weight.

14. The apparatus according to claim 1, wherein the first diffusion unit generates the video signal to display the gray scale level in the first gray scale group which is obtained by adding or subtracting the value corresponding to the gray scale to be displayed to or from the gray scale level in the second gray scale group when the converted gray scale level from the gray scale conversion unit is in the second gray scale group.

15. The apparatus according to claim 1, further comprising a second diffusion unit for diffusing a difference between the gray scale level of pixel to be displayed and the converted gray scale level to pixels adjacent to the pixel to be displayed with predetermined ratio.

16. The apparatus according to claim 15, wherein the second diffusion unit determines a value to be diffused in horizontal direction based on a lower bits of all bits which indicate the gray scale level of pixel to be displayed, and a value

to be diffused in vertical direction based on a value obtained by removing the lower bits from a difference between the gray scale level of the pixel to be displayed and the converted gray scale level.

17. A display method for performing gray scale display by dividing one field of picture into a plurality of weighted subfields and by controlling each subfield to emit or not emit based on the gray scale level of pixel in the picture, said method comprising:

selectively converting a gray scale level of the pixel to one gray scale level in a first gray scale group or one gray scale level in a second gray scale group, said first gray scale group including a plurality of gray scale levels to be used for actual display, the gray scale level in the first gray scale group being expressed by the combination of the subfields, said second gray scale group including a plurality of gray scale levels each of which is in the middle of the gray scale levels in the first gray scale group; and

generating video signal, said video signal displaying a gray scale level obtained by the conversion when the gray scale level obtained by the conversion is in the first gray scale group, or a gray scale level in the first gray scale group which is obtained by diffusing a predetermined value corresponding to the gray scale level in the second gray scale group when the gray scale level obtained by the conversion is in the second gray scale group.

18. The method according to claim 17, wherein the first gray scale group includes gray scale levels each of which is achieved by subfields in which there is no non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level.

19. The method according to claim 17, wherein the first gray scale group includes gray scale levels each of which is achieved by subfields in which there is at most one of non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level.

20. The method according to claim 17, wherein the first gray scale group includes gray scale levels each of which is achieved by subfields in which there is at most two of non-emitting subfields in subfields having weights less than the greatest weight among weights of the subfields to be emitted for achieving the gray scale level.

21. The method according to claim 18, wherein said non-emitting subfield excludes a subfield having the minimum weight.

22. The method according to claim 19, wherein said non-emitting subfield excludes a subfield having the minimum weight.

23. The method according to claim20, wherein said non-emitting subfield excludes a subfield having the minimum weight.

24. The method according to claim 18, wherein said non-emitting subfield excludes a subfield having the minimum weight and a subfield having the next succeeding minimum weight.

25. The method according to claim 19, wherein said non-emitting subfield excludes a subfield having the minimum weight and a subfield having the next succeeding minimum weight.

26. The method according to claim 20, wherein said non-emitting subfield excludes a subfield having the minimum weight and a subfield having the next succeeding minimum weight.

27. The method according to claim 18, wherein said non-emitting subfield excludes a subfield having the minimum weight, a subfield having the next succeeding minimum weight and a subfield having the third succeeding minimum weight.

28. The method according to claim 19, wherein said non-emitting subfield excludes a subfield having the minimum weight, a subfield having the next succeeding minimum weight and a subfield having the third succeeding minimum weight.

29. The method according to claim 20, wherein said non-emitting subfield excludes a subfield having the minimum weight, a subfield having the next succeeding minimum weight and a subfield having the third succeeding minimum weight.

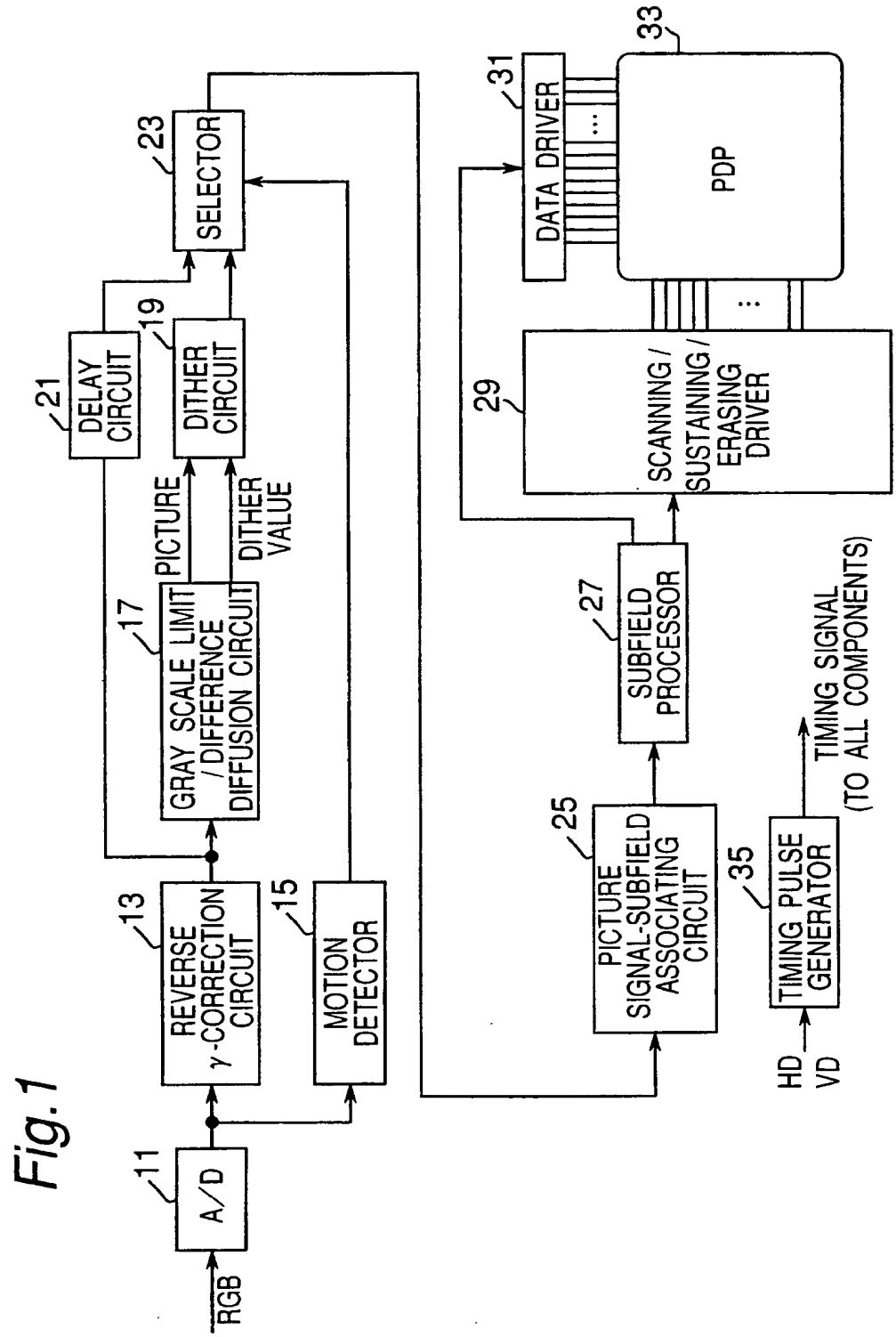
30. The method according to claim 17, wherein the first diffusion unit generates the video signal to display the gray scale level in the first gray scale group which is obtained by adding or subtracting the value corresponding to the gray scale to be displayed to or from the gray scale level in the second gray scale group when the converted gray scale level from the gray scale conversion is in the second gray scale group.

31. The method according to claim 17, further comprising diffusing a difference between the gray scale level of pixel to be displayed and the converted gray scale level to pixels adjacent to the pixel to be displayed with predetermined ratio.

32. The method according to claim 31, wherein the second diffusion unit determines a value to be diffused in horizontal direction based on a lower bits of all bits which indicate the gray scale level of pixel to be displayed, and a value

to be diffused in vertical direction based on a value obtained by removing the lower bits from a difference between the gray scale level of the pixel to be displayed and the converted gray scale level.

Fig.1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A/D
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REVERSE γ-CORRECTION CIRCUIT
13
MOTION DETECTOR
15
GRAY SCALE LIMIT /DIFFERENCE DIFFUSION CIRCUIT
17
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DITHER VALUE
DELAY CIRCUIT
21
DITHER CIRCUIT
19
SELECTOR
23
PICTURE SIGNAL-SUBFIELD ASSOCIATING CIRCUIT
25
SUBFIELD PROCESSOR
27
SCANNING / SUSTAINING / ERASING DRIVER
29
DATA DRIVER
31
PDP
33
TIMING PULSE GENERATOR
35
HD
VD
TIMING SIGNAL (TO ALL COMPONENTS)

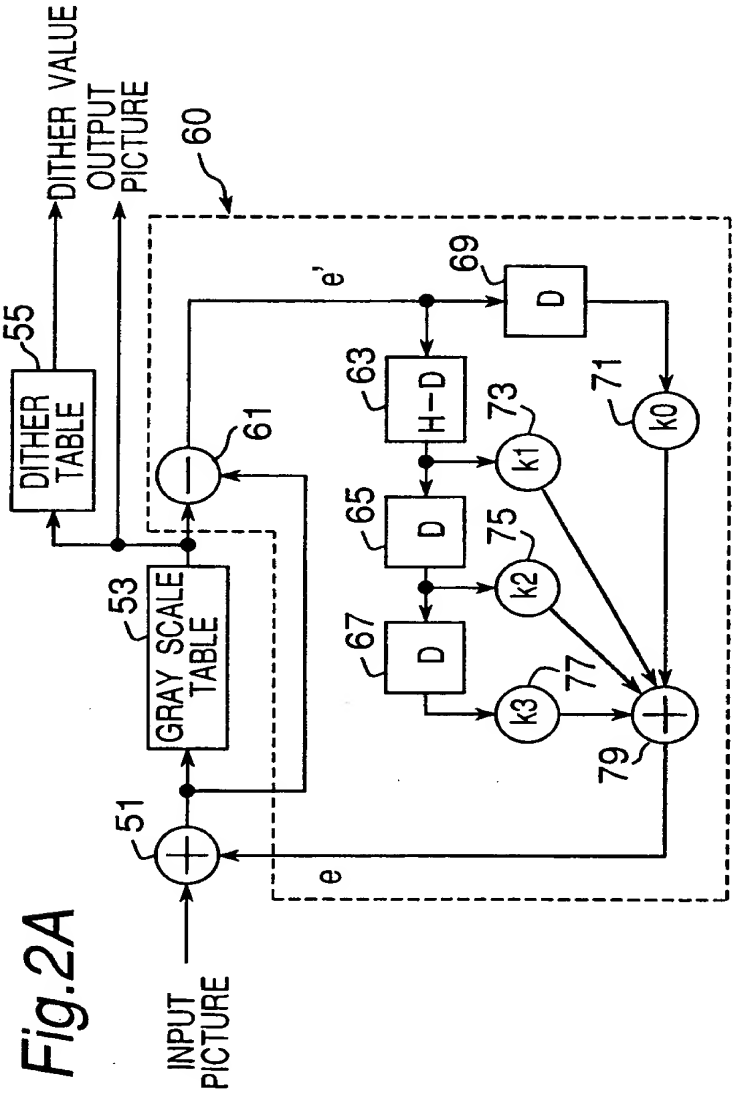


Fig.2A

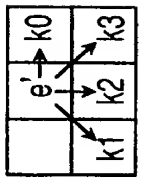


Fig.2C

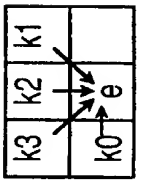


Fig.2B

Fig.3A

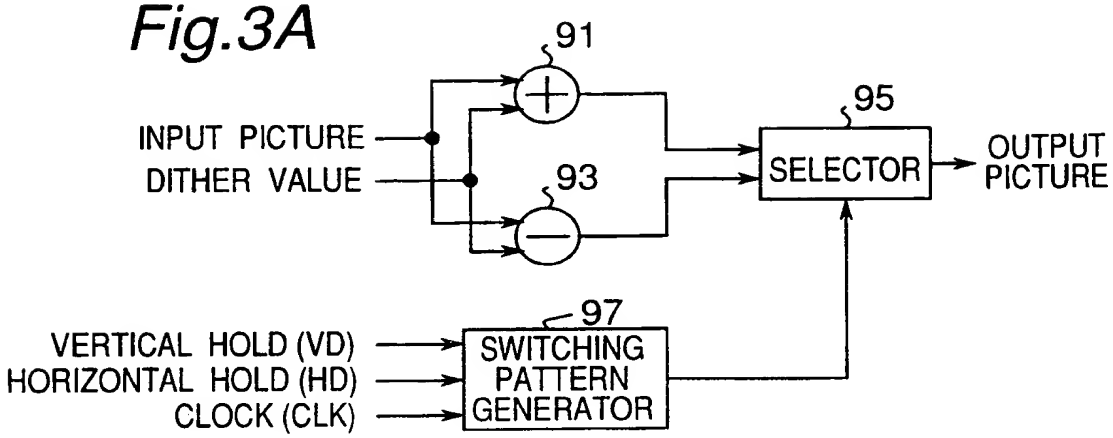


Fig.3B

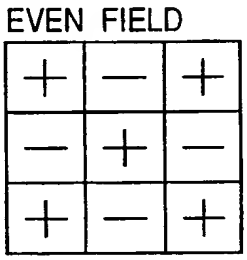


Fig.3C

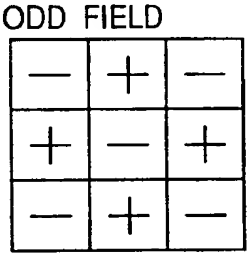


Fig.3D

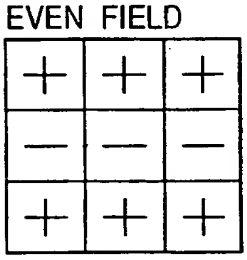


Fig.3E

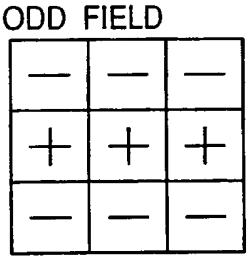


Fig.3F

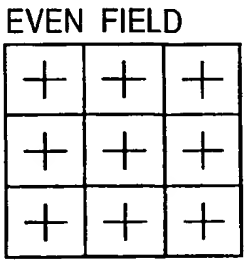


Fig.3G

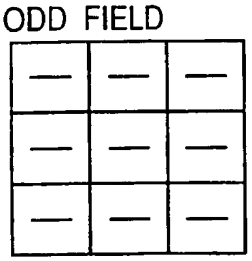
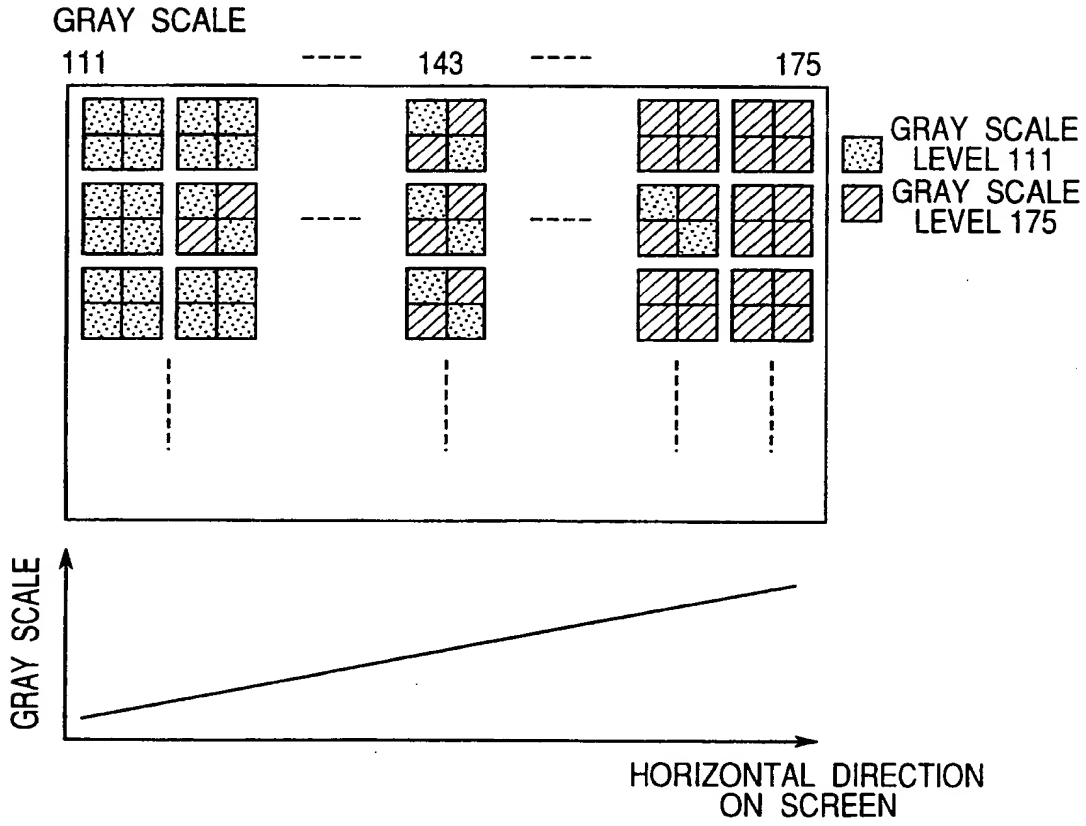


Fig.4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143
175
GRAY SCALE LEVEL 111
GRAY SCALE LEVEL 175
GRAY SCALE
HORIZONTAL DIRECTION ON SCREEN

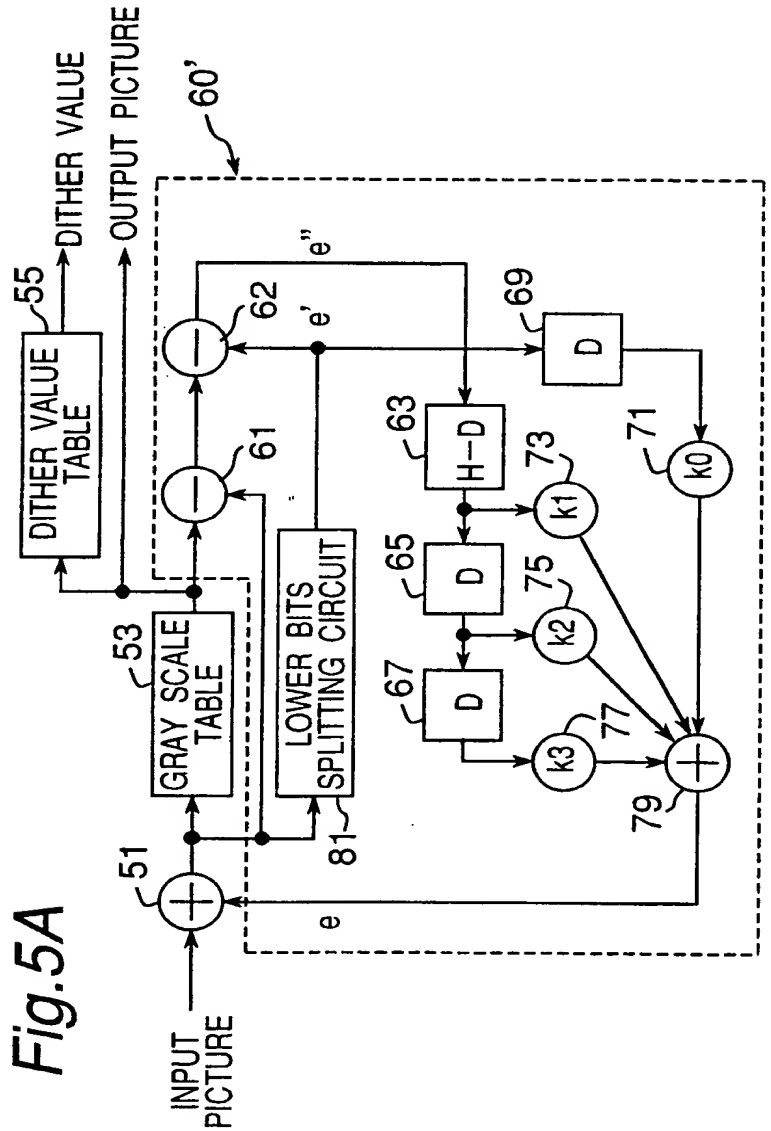


Fig.5A

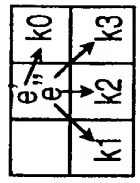


Fig.5C

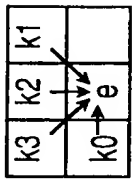


Fig.5B

Fig.6 PRIOR ART

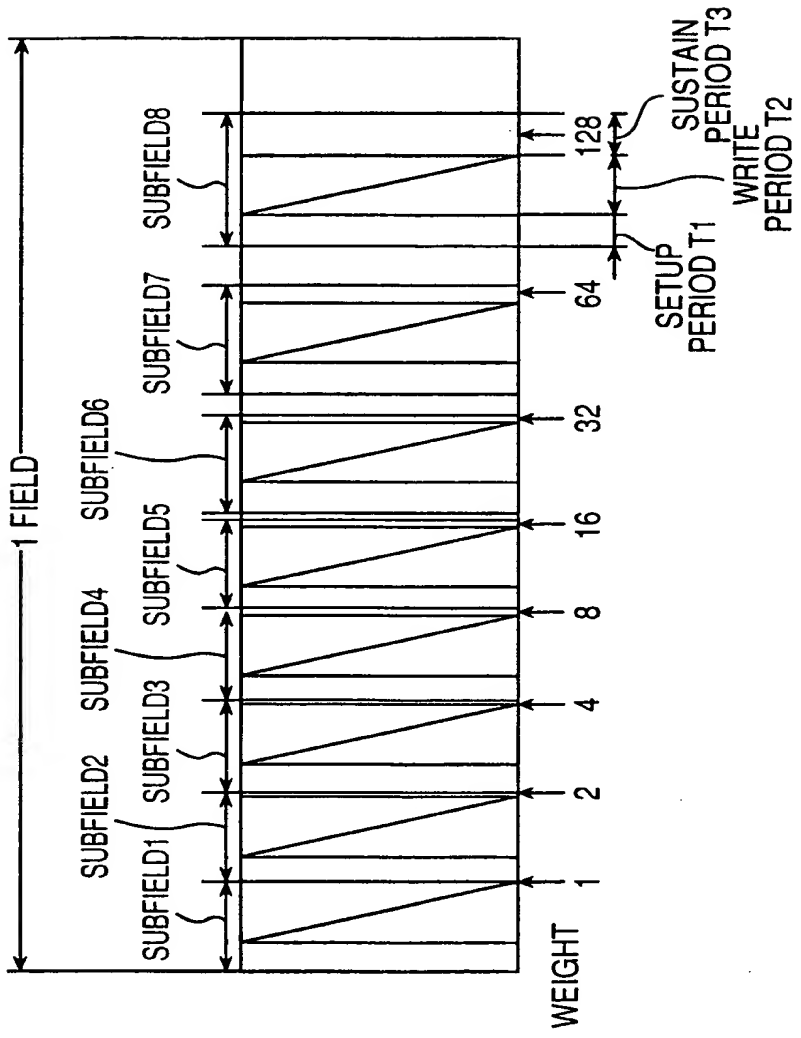


Fig.7 PRIOR ART

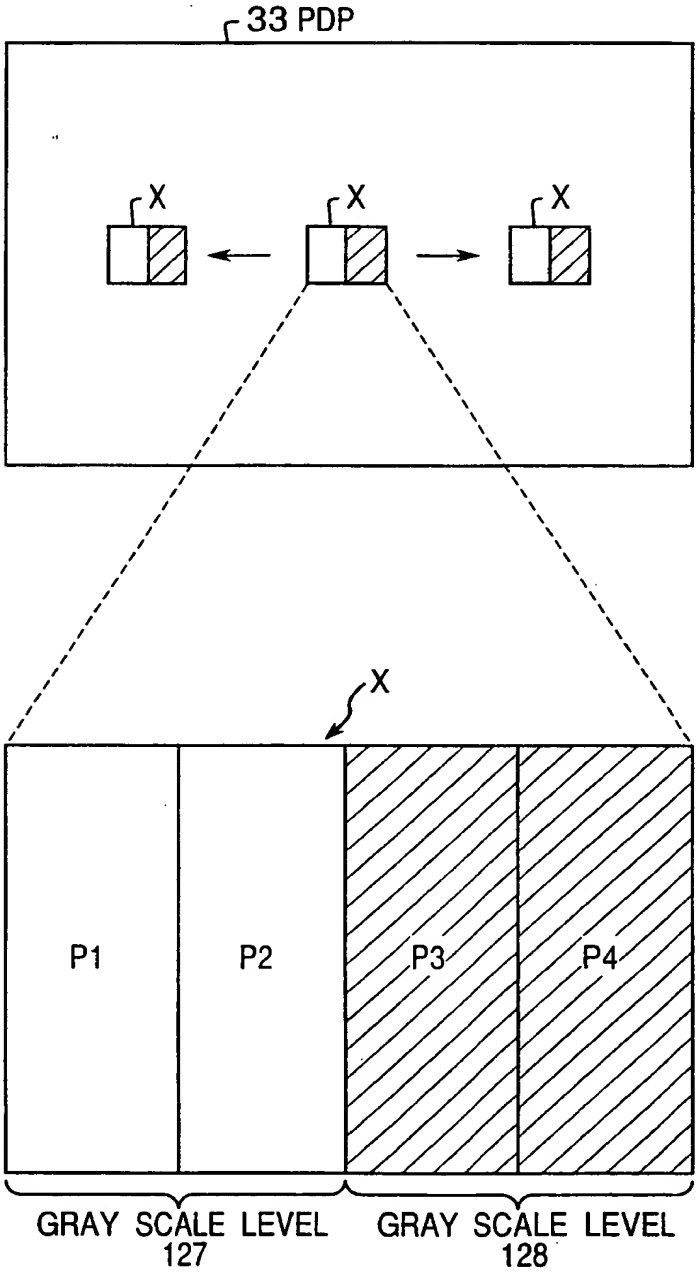
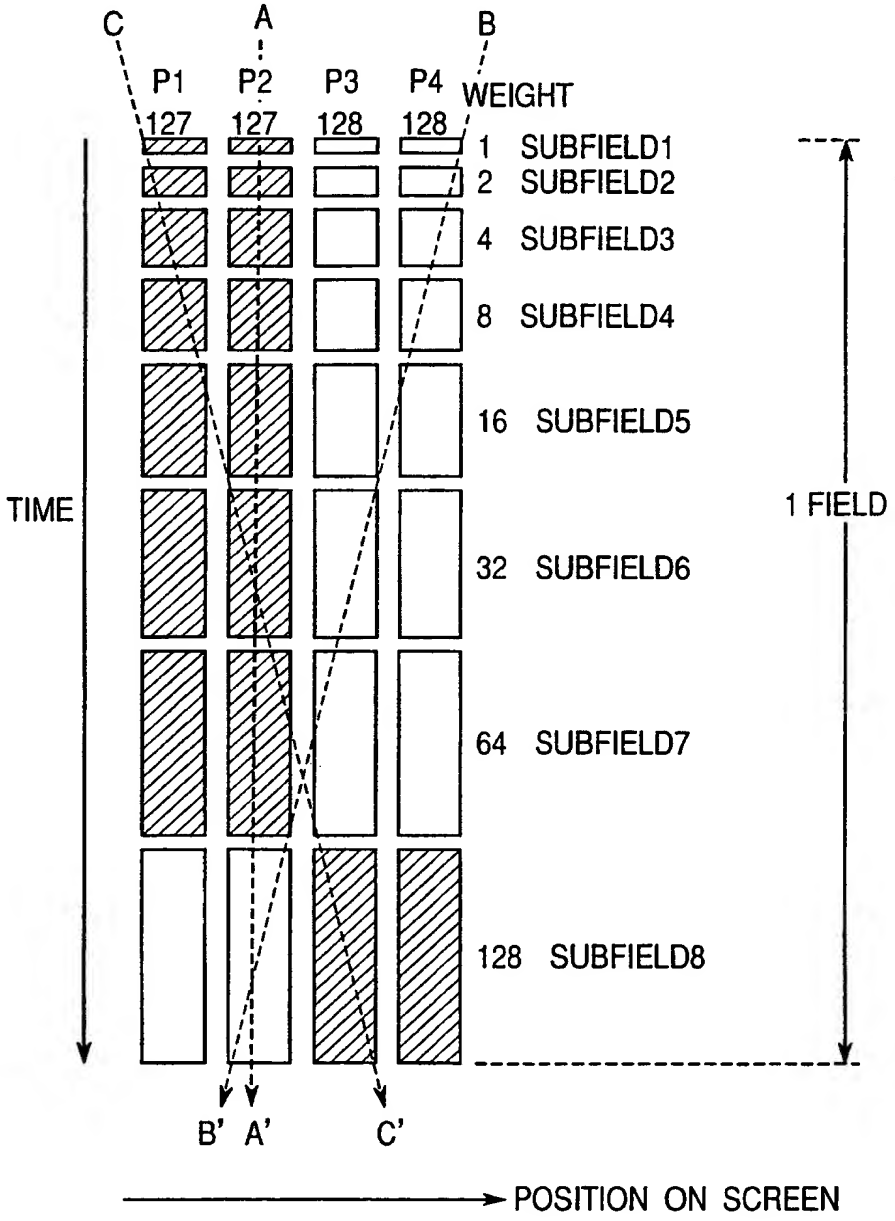


Fig.8 PRIOR ART



INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 00/00193

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G09G3/28 G09G3/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 740 253 A (FUJITSU LTD.) 25 April 1997 (1997-04-25)	1,17
A	abstract page 28, line 1 -page 31, line 5 page 54, line 15 - line 28; figures 17-20,57-71	2-16, 18-32
X,P	EP 0 893 916 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 27 January 1999 (1999-01-27)	1,17
A	abstract column 4, line 49 -column 5, line 17 column 7, line 52 -column 8, line 13 column 12, line 43 - line 50 column 14, line 3 - line 20; figures 1,2,11	2-16, 18-32

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
7 June 2000	15/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	O'Reilly, D

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/JP 00/00193

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2740253 A	25-04-1997	JP 10031455 A	03-02-1998
EP 893916 A	27-01-1999	JP 11231827 A	27-08-1999
		JP 11212517 A	06-08-1999

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International Bureau

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11/14446 22 January 1999 (22.01.99) JP

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(74) Agents: AOYAMA, Tamotsu et al.; Aoyama & Partners, Imp Building, 3-7, Shiromi 1-chome, Chuo-ku, Osaka-shi, Osaka 540-0001 (JP).

(81) Designated States: CN, KR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

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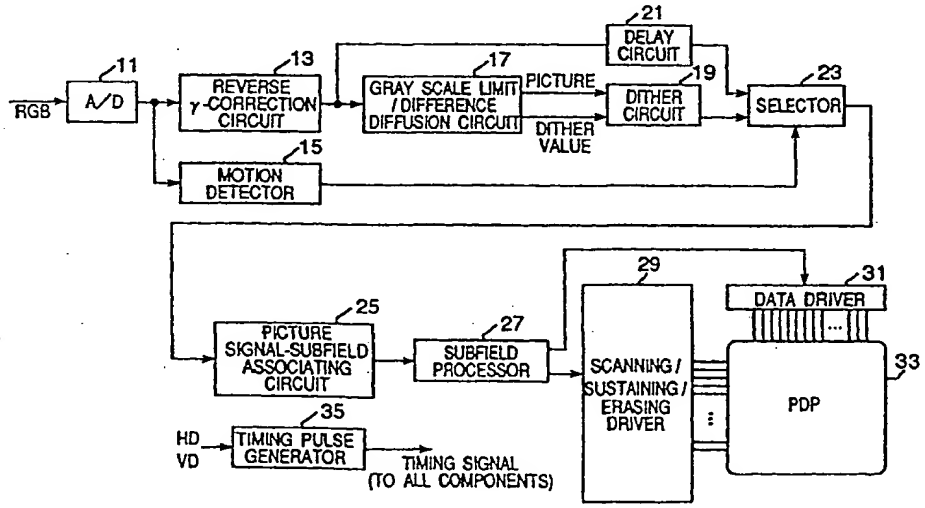
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

THE V

(54) Title: APPARATUS AND METHOD FOR MAKING A GRAY SCALE DISPLAY WITH SUBFRAMES



(57) Abstract

The invention provides an apparatus and a method applied to a plasma display panel or other display panel, achieving a gray scale display by using a plurality of weighted subfields. The apparatus comprises a gray scale limiting/difference diffusion circuit (17) for converting gray scale levels in a supplied image signal to specific gray scale levels that do not easily create pseudo contours in moving picture areas and to intermediate gray scale levels between the specific gray scale levels, and diffusing the difference between the converted gray scale level and the original gray scale level to adjacent pixels, and a dither circuit (19) for generating a video signal to display the converted gray scale level from the circuit (17) alternately in even and odd fields. The dither circuit (19) generates the video signal in which the gray scale levels offset the dither level above and below the dithered gray scale are alternately presented when the converted gray scale level is a dithered gray scale.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
661451		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/JP 00/00193	18/01/2000	22/01/1999

Applicant

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al.

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

[ ] the text is approved as submitted by the applicant.

[X] the text has been established by this Authority to read as follows:

APPARATUS AND METHOD FOR MAKING A GRAY SCALE DISPLAY WITH SUBFRAMES

5. With regard to the **abstract,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

[X] as suggested by the applicant.

[ ] None of the figures.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 00/00193

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G09G3/28 G09G3/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 740 253 A (FUJITSU LTD.) 25 April 1997 (1997-04-25)	1,17
A	abstract page 28, line 1 -page 31, line 5 page 54, line 15 - line 28; figures 17-20,57-71	2-16, 18-32
X,P	EP 0 893 916 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 27 January 1999 (1999-01-27)	1,17
A	abstract column 4, line 49 -column 5, line 17 column 7, line 52 -column 8, line 13 column 12, line 43 - line 50 column 14, line 3 - line 20; figures 1,2,11	2-16, 18-32

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 June 2000	15/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	O'Reilly, D

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/JP 00/00193

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2740253 A	25-04-1997	JP 10031455 A	03-02-1998
EP 893916 A	27-01-1999	JP 11231827 A	27-08-1999
		JP 11212517 A	06-08-1999